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AISTech 2006

The Iron & Steel Technology Conference and Exposition

May 1–4, 2006
Cleveland Convention Center
Cleveland, Ohio, USA

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Final Program

2:30 p.m.
Development and Application of BRP Technology at Baosteel
Z-X. Lu and X-F. Jiang, Baosteel

3 p.m. – Break

✦3:30 p.m.
The Results of Four Years of Commercial Operations of Praxair's BOF Cojet® Gas Injection System
C.J. Messina, J. Kelly, J. Jones, C. Kaufmann and M.F. Riley, Praxair Metals Technologies

✦4 p.m.
A Contribution to the Dynamic Process Simulation of the BOF Process
C. Chigwedu, Mittal Steel USA, and J. Kempken, SMS Demag AG

✦4:30 p.m.
Cold Shroud Oxygen Blowing for Improvement in Converter Productivity
J. Batham and A. Richardson, BOC Group; T. Balkos, A.H. Tallman Bronze Co. Ltd.; and W. Howanski and R.E. Fash, Mittal Steel USA

1:30 p.m. – Continuous Casting – Mold Operations *Room 230A*

✦Session Chairs: J. Young, Hatch Ltd.; L. Beitelman, ABB Inc.; C. Ricciuti, CCR Technologies Inc.; T. Tsai, Mittal Steel USA; T. Rumler, Siemens VAI; and B. Thomas, University of Illinois at Urbana-Champaign

✦1:30 p.m.
Superior Slab Casting Using Electromagnetics
H.R. Hackl, S.G. Kollberg, J.E.A. Eriksson and A.F. Lehman, ABB Automation Technologies AB

2 p.m.
Innovative Control Methods to Overcome Periodic Disturbances on Continuous Caster Mold Level
M. Dussud and F. Montegu, SERT; G. Kim and S. Lee, POSCO; J. Lottin, University of Savoie; and E. Fortaleza, IFP

3 p.m. – Break

3:30 p.m.
Developments on Fluid Flow and Heat Flow Theories in the Continuous Casting Mold
R.D. Morales and P. Ramírez-López, National Polytechnic Institute – ESIQIE

4 p.m.
Mathematical Modeling of Thermal-fluid Flow in the Meniscus Region During an Oscillation Cycle
C. Ojeda and J. Barco, Labein Tecnilia; J. Sengupta and B.G. Thomas, University of Illinois at Urbana-Champaign, and J.L. Arana, University of Basque Country

4:30 p.m.
New Sensor Improves Productivity and Quality
P. Mueller, Salzgitter Flachstahl GmbH, and I. Schubert, Engineering Partner GmbH

1:30 p.m. – Sheet Rolling/Plate Rolling/Process and Product Metallurgy – Product Quality in Rolling and Finishing *Room 205B*

✦Session Chairs: D. Elwood, Mittal Steel USA; B. Vaill, Oregon Steel Mills; and J. Tiley, Hatch Associates

1:30 p.m.
When to Change Descaling Nozzles and How to Interpret Board Tests
D.T. Blazevic, Hot Rolling Consultants Ltd.

2 p.m.
New Descale Nozzle Technology Greatly Enhances the Removal of Scale While Reducing the Consumption of Electricity and Descale Water Through Which Energy Is Saved
K. Karube, JFE Steel Corp., and T. Nishiyama, Kyoritsu Gokin Co. Ltd.

2:30 p.m.
In-situ Study of Scale Formation Under Finishing Mill Operating Conditions
W.M. Melfo, M. Reid and R.J. Dippenaar, University of Wollongong

3 p.m. – Break

3:30 p.m.
Evolution of Artificially Induced Slab Imperfections Through Hot and Cold Rolling
M. Merwin, U. S. Steel Corp., and P. Zahumensky, U. S. Steel Corp. Košice

4 p.m.
Reduction of Surface Defects on 0.25 Percent C Hot Band at Nucor Steel Indiana
S.T. McDougal, Nucor Steel

4:30 p.m.
The Application of Electron Backscatter Diffraction (EBSD) for Measurement of Texture and as a Process Optimization Tool for Cold and Hot Metal Rolling
A. Fisher, S. Wright and M. Nowell, EDAX

1:30 p.m. – Coating and Process Lines – Galvanizing/Coating Lines *Room 205C*

✦Session Chairs: M. Matas, CMI EFCO Inc., and G. Vellente, Ajax Tocco Magnethermic Corp.

1:30 p.m.
New Opportunities for In-line Paint Applications in Galvanizing Lines
K.K.O. Bär, AdPhos Steel GmbH; and J. Anderson and N. Frederiksen, AdPhos North America Inc.

New Descale Nozzle Technology Greatly Enhances the Removal of Scale While Reducing the Consumption of Electricity and Descale Water Through Which Energy is Saved

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Kyoritsu Gokin Co., Ltd.

INTRODUCTION

Descaling systems are an indispensable part in achieving surface quality in the steel making process. With an ever-increasing need to deliver cleaner, higher performance and quality steels used for a broader range of applications, descaling plays an increasingly more critical function in meeting those challenging demands.

As a result, new descale nozzle technology was developed to allow more efficient removal of scale from steel surfaces. Furthermore, this new descale nozzle technology utilizes water more efficiently, thereby providing options that were not previously possible. Namely descaling with lower operating pressures, and/or reduced water consumption. Additional potential benefits are, reduced reheat furnace temperatures and deeper penetration of steel surface.

DEVELOPMENT HISTORY

Every Hot Strip Mill is equipped with a descaling system (Figure 1 & 2) for the removal of scale from steel surfaces that is generated from the reheating of a slab/bar. Without the descaling system, the formed scale will be rolled into the strip surface leading to poor surface finish and other quality related issues. Descaling systems are mainly positioned at the inlet of Roughing and Finishing Mills to spray high pressure water onto steel surface. This descaling system is indispensable to achieving the ever demanding need to improve on uniform surface quality.

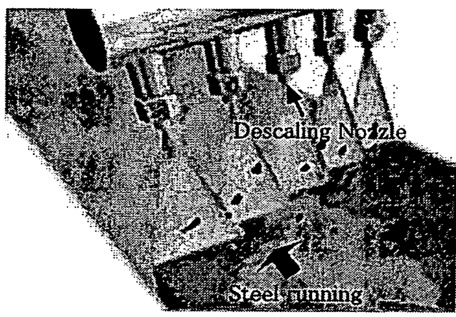


Figure 1 Outline of Descale System

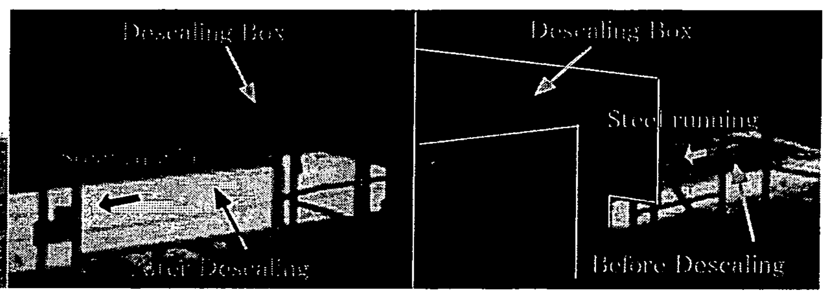


Figure 2 Steel running through Descale System

The newly developed descale nozzles not only offer improved performance in removing scale sticking to steel surfaces but also a potentially large saving of high pressure water consumption (15 to 60 MPa). Figure 3 shows an outline of new descale nozzle.

Descale Nozzle consists of cap, nozzle tip, packing, straightener/filter and adapter. The length of straightener/filter can be adapted to a descaling system's specification and can be combined with a check valve to provide a quick ON/OFF response action.

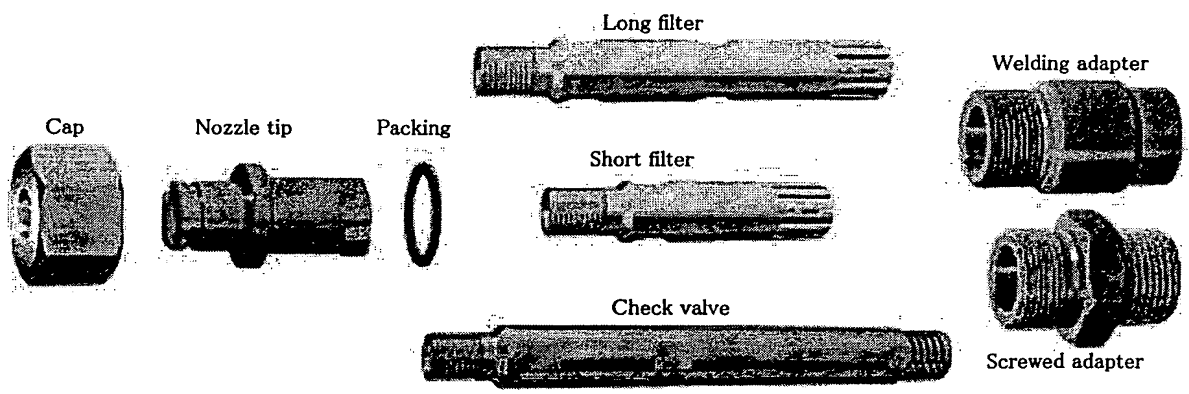


Figure 3 Descale Nozzle Components

To illustrate the benefits of the new descale nozzle technology when compared to the conventional descale nozzle technology, erosion test utilizing anodized aluminum plate were performed as per Figure 4.
The test conditions are:

Spray pressure: 15Mpa
Flow rate : 111 liter/min
Spray distance: 129mm

The results are shown in Figure 5 which illustrate the improved performance of the new descale nozzle. By installing this new descale nozzle in a descaling system, surface defect ratio from scale can be significantly reduced. In addition, high pressure water consumption can be cut by maximum 40%, and pump's electricity consumption by 10 to 15%.

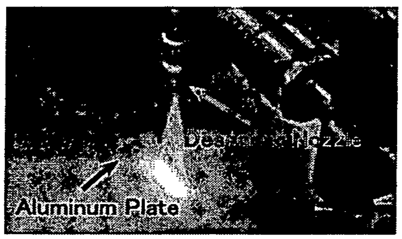


Figure 4 Erosion-test on aluminum plate

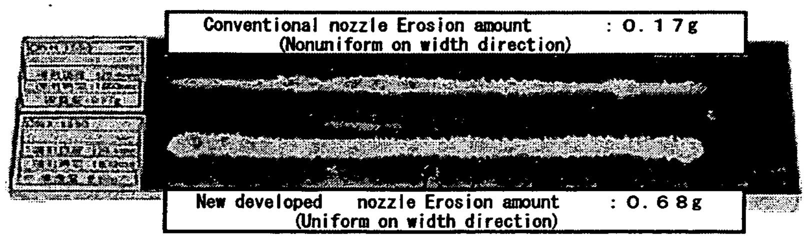


Figure 5 Result of Erosion-test on aluminum plate

RESULTS AND DISCUSSION

Development History:
A descale system (Figure 1 & 2) is located in a Hot Strip Mill for the purpose of removing scale from the steel surface through the utilization of high pressure water (15 to 60 MPa).

This process encounters two distinct issues, namely :

1. the high consumption of electricity by the descale pumps , with the added disadvantage of not being environmentally friendly.
2. a tendency to increase the operating pressure and water consumption to improve descaling efficiency

The objective that was set forth for the development of the new descale nozzle technology, was to demonstrate that improvements could increase the descaling system's efficiency with a minimal system's modification cost, and at the same time realize savings in water and electricity consumption by the descale pump.

In order to evaluate and document the performance of the new descale nozzle design, a test model had to be created that would closely examine the two (2) critical issues.
Namely:

1. The design of a model to evaluate the nozzle's performance that is not only based on pressure and flow rate, but also because of impinging force and internal flow dynamics.
2. The design of the nozzle's internal structure based on the above model that would evaluate the nozzle's descale water flow capacity.

After having successfully addressed the fluid dynamics and mechanical issues, a new world class descale nozzle was obtained.

Evaluation Model of Descaling Ability

As illustrated in Figure 6, the surface erosion created from descaling is the result of the water impinging pressure ρ CU when striking the steel surface.

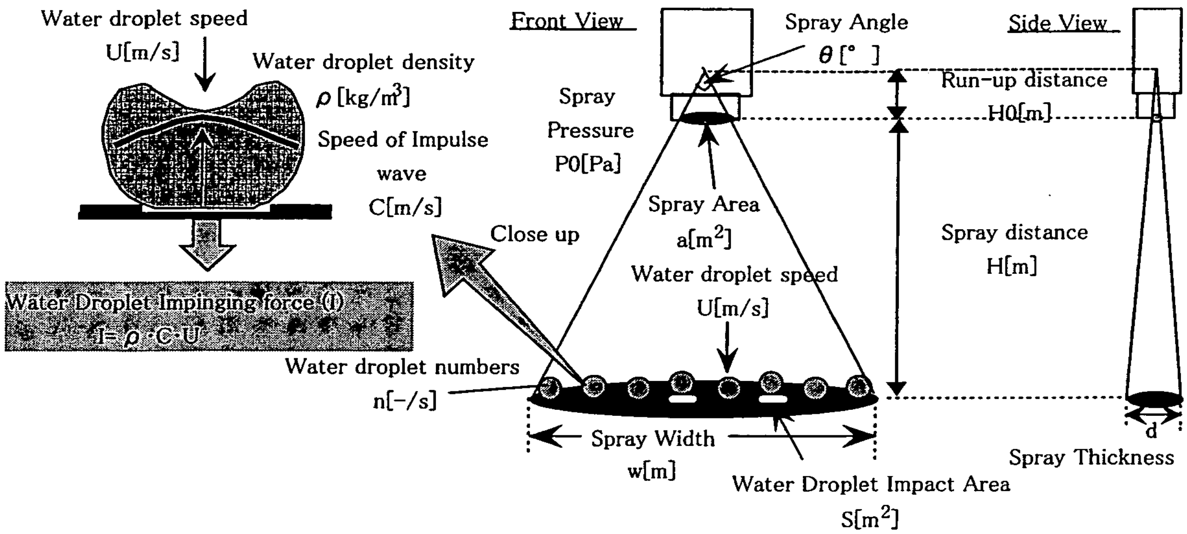


Figure 6 Principle of impinging wave and concept of evaluation model of descaling capacity

Efficient descaling is dependent on three factors:

1. Total impinging force of water droplet (Fi[N])
2. Total impinging force per unit area of water droplet (Ei[Pa])
3. Descaling time.

Based on these factors, a model to evaluate the nozzle's capacity was set up, and total impinging force Fi and unit area impinging force Ei was calculated by the following formula.

$$Fi[N]=n\times\rho\ cu\times S\times t=\frac{Q}{\frac{4}{3}\pi\left(\frac{D}{2}\right)^3}\times\rho\ cu\times\pi\left(\frac{D}{2}\right)^2\alpha\times t=U^2\times a\times\rho\times C\times\frac{3}{2D}\times\alpha\times t$$

$$=P0\times a\times C\times\frac{3}{D}\times\alpha\times t\cdots(1)$$

$$Ei[Pa]=\frac{U^2\times a\times\rho\times C\times\frac{3}{2D}\times\alpha\times t}{a\left(\frac{H}{H0}\right)^\beta}\fallingdotseq\frac{U^2\times a\times\rho\times C\times\frac{3}{2D}\times\alpha\times t}{\pi\times w\times d\times\frac{1}{4}}\cdots(2)$$

n: water droplet number [-/s]	α: water droplet impinging coefficient [-]
ρ: water droplet density [kg/m³]	P0: pressure [Pa]
C: sound speed [m/s]	H: spray distance [m]
u: water droplet flow [m/s]	H0: run-up distance [m]
S: water droplet impinging area [m²]	β: spray form coefficient [-]
t: water droplet impinging time [s]	W: spray width [m]
Q: flow rate [m3/s]	d: spray thickness [m]
D: water droplet diameter [m]	

The next step in the test phase was to verify descale nozzle capacity.

Actual test in Hot Strip Mill condition utilizing different descale nozzle designs is generally unrealistic as this can affect the quality of the product as well as a long term quality reliability. This is particularly the case with the reduction of water volume as there is always a higher risk of inferior product quality.

With these issues in mind, it was necessary to set up an off-line test model to evaluate the nozzle's capacity.

As shown in Figure 7, it was learned that aluminum plate had similar hardness characteristics at ambient temperatures as steel did at the temperature range with which it should be descaled. It was also discovered that the abrasion volume of aluminum plate and removal ratio of steel's scale had the similar correlation. (See Figure 8.)

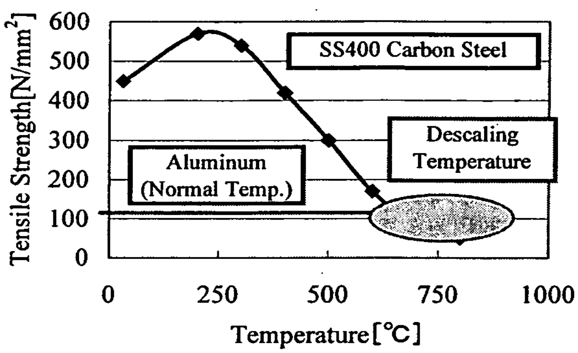


Figure 7 Relation between temperature and steel tension strength

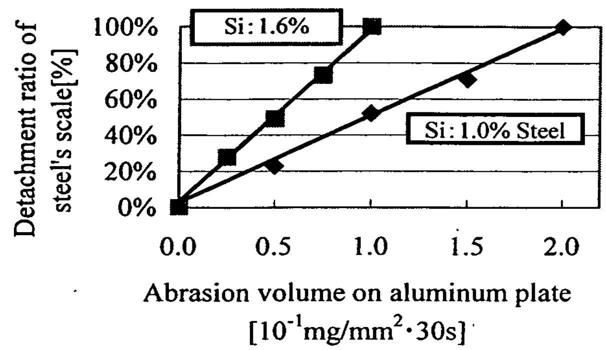


Figure 8 Relation between abrasion on aluminum plate and detachment ratio of steel's scale

Based on this data, facts, and in order to have an off-line quantitative evaluation of the nozzle's capacity, we decided to use aluminum plate.

Its descaling capacity was calculated by the formula (1) and (2), which was plotted in Figure 9. As a result it was discovered that descaling capacity could be evaluated with total impinging force (Fi[N]) and unit impinging force (Ei[Pa]) quantitatively.

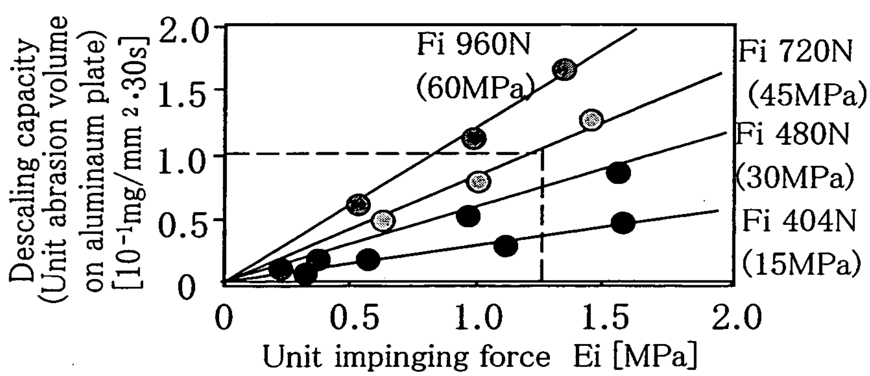


Figure 9 Descaling capacity evaluation based on Fi and Ei

Optimization of Internal Nozzle Design

Based on the evaluation model of descaling capacity, the internal Design of the descale nozzle was optimized. The key point of this optimization was to improve total impinging force (Fi[N]) and unit impinging force (Ei[Pa]) by making the water droplet speed (U) faster and minimizing the spray thickness (d) as shown Figure 6. As a result, the internal flow analyses of the nozzle during the trial phase were repeated as per Figure 10, and an optimized design was successfully achieved as per Figure 11.

It relates to:

① Nozzle internal gutter (pattern) caliber

② size of the straightener

③ position of the straightener

④ shape of the nozzle tip

As a result, the droplet speed (U) was improved, and the spray width (thickness) (d) was decreased to about two-thirds of that of a conventional nozzle as Figure 12 shows. Figure 13 shows the new Descale Nozzle design with much more than double the descaling capacity than that of a conventional descale nozzle. Furthermore, the new nozzle has a flatter distribution impinging force across the spray width direction when compared to a conventional nozzle as per Figure 14 illustrates. The descaling performance across the entire spray length is optimized so much that an improved steel quality can be guaranteed.

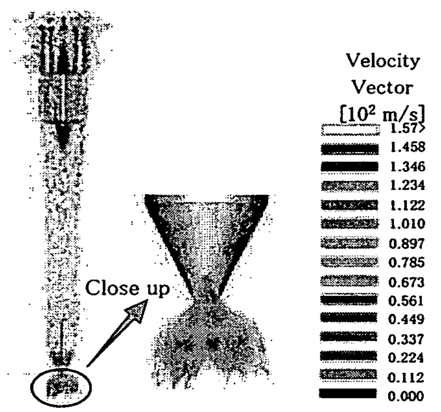


Figure 10 Sample of flow analysis inside nozzle

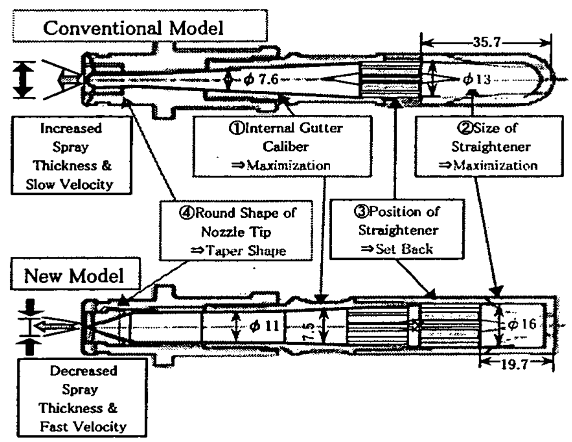


Figure 11 Optimized design of nozzle internal structure

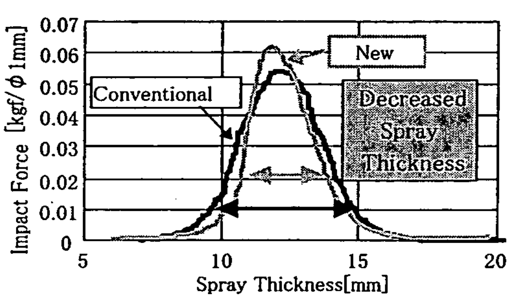


Figure 12 Impinging force distribution of spray thickness direction

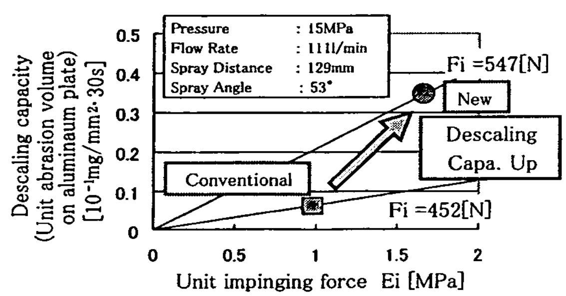


Figure 13 Improved descaling capacity of new nozzle

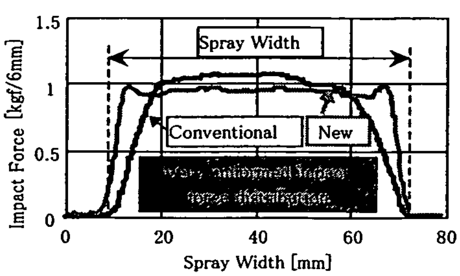


Figure 14 Impinging force Distribution of spray width

Effect of Introduction

The new descale nozzles were installed at JFE Steel Corporation's Hot Strip Mills in the following sequence :

1. Kurashiki: Hot Strip Mill, Plate Mill, Sections
2. Fukuyama: Hot Strip Mill No. 1 & 2
3. Keihin: Hot Strip Mill, Plate Mill
4. Chita: Seamless Pipe Mill

The results are shown in Table No. 1.

The improvement in steel surface quality as well as a reduction in water consumption of up to 40%can contributes to electricity saving of about 1 kWh/t per consumption unit.

The reduction in water consumption means that the temperature drop in the steel can be limited. Therefore the temperature requirement for re-heating steel before rolling can be reduced by 10° to 20°C, with savings of about 20MJ/t per furnace heating fuel consumption units.

As a result, emissions to the environment can be greatly reduced.

JFE Steel Corp committed to installing this new descale nozzle in of all their Hot Strip, Plate, and Seamless Mills. We also actively plan to market this new Descale Nozzle to domestic and overseas steel mills.

As Hot Strip Mills start to use the new Desacle Nozzle, we are proud to make this great contribution to CO_2 reduction along with the added savings in electricity fuel consumption.

Next, please see Table No. 3 that shows the technical comparison of the new and conventional nozzles.

With the conventional descaling system, descaling capacity was measured by the impact force on a steel surface based on spray pressure and water flow rate. To achieve better descaling, a descaling system had to be converted to higher pressures and larger water volumes. Higher pressure systems required huge conversion costs of several hundred million yen as well as increased electricity consumption and maintenance costs due to shorter nozzle, pump and valve life. Larger volumes of water also required increased electrical consumption and higher steel temperatures to offset the increased cooling effect. The new descale nozzles together with their new filters will fit into existing headers without the need for costly modifications. The time it takes to change a descale header is therefore shorter and more cost effective and provides for an opportunity to evaluate the new nozzle performance more readily.

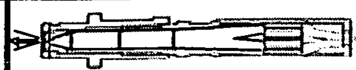
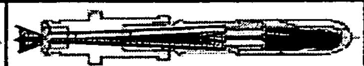
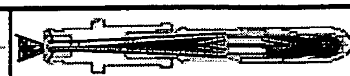
Table 1 New descale nozzle's effect on JFE rolling line (compared with conventional nozzle)

	Scale defect on Steel: Outbreak ratio	Descaling high pressure water: Reduction	Descale pump: Electricity consumption unit Reduction	Heating furnace: Fuel consumption unit Reduction
Effect	**50% less**	**Max. 40%**	**1kWh/t**	**20MJ/t**

Table 2 Energy-savings results when all nozzles are replaced with the new descale nozzles.

	Steel Production per year	Descale pump electrical saving per year			Reheat furnace fuel saving per year			Total savings per year	
		Energy saved	CO_2 reduced	Cost Saved	Energy saved	CO_2 reduced	Cost Saved	CO_2 reduced	Cost Saved
in all JFE Steel Mills	24 mln t / year	24 GWh/year	11,000 t/year	US$ 2.2 mln / year	480 TJ /year	44,000 t/year	2 mln/year	54,000t/year	4.5 mln/year
in all Japanese Steel Mills	101 mln t /year	10GWh/year	44,000 t/year	US$ 9.2 mln /year	2,020 TJ /year	184,000 t/year	8.7 mln/year	229,000t/year	18 mln/year
in all Global Steel Mills	948 mln t /year	948 GWh/year	417,000 t/year	US$ 86 mln /year	18,960 TJ/year	1,728,000 t/year	82 mln/year	2,145,000t/year	168 mln/year

Table 3 Technical comparison between new- and conventional technology

	New Technology	Conventional Technology	
Outline	 New Developed Descaling Nozzle	 High Pressurized 15→30 MPa	 Double water volume
Pressure	15MPa	30MPa	15MPa
Descaling Water Volume	40% Reduced	Unchanged	100% Increased
Conversion Cost	Less than US$100,000	More than US$1,000,000	About US$1,000,000
Time of Shut down for Conversion	5－10hours	5－10days	5－10days
Nozzle Life	Unchanged	50% Decreased	Unchanged
Effect of descaling capacity increased	Double	Double	Double
Descaling pump's electricity consumption unit	1kWh/t Reduced	2－3kWh/t Increased	2－3kWh/t Increased
Heating temperature of slab	10－20℃ Reduced	Unchanged	20－30℃ Increased

CONCLUSION

1) This technical development enabled us to successfully introduce the next-generation descale nozzle with its world-class descaling capabilities.
   ① Set-up of a decale capability evaluation model to closely observe descaling pressure, flow rate and nozzle structure as well as spray surface impact.
   ② The evaluation of the optimization process for internal nozzle design based on this evaluation model.
2) New descale nozzles were introduced on Hot Strip Mill at JFE Steel in April 2003. Since then, they have performed successfully contributing greatly to energy-savings as well as the production of enhanced surface quality and the reduction in the descale pump maintenance cost.
3) We are also pleased to announce that many of steel mills around the world have shown keen interest in the new develop descale nozzles. In order to meet worldwide demand, we have increased our manufacturing capacity so that we can respond to inquires and orders on a timely basis.
   In addition, we are contributing to a reduced strain on the environment.

ACKOWLEDGEMENTS

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1) "Water Jet Technique Dictionary" published by Japan Water Jet Association, P76, Mazuzen